Lecture 19 – Skeletal System and Bones

- The skeletal framework of the body is subdivided into axial skeleton (skull, vertebral column, ribs & sternum) and appendicular skeleton (limbs and limb girdles)
- The skeletal system includes bones and cartilage

Function of skeletal system

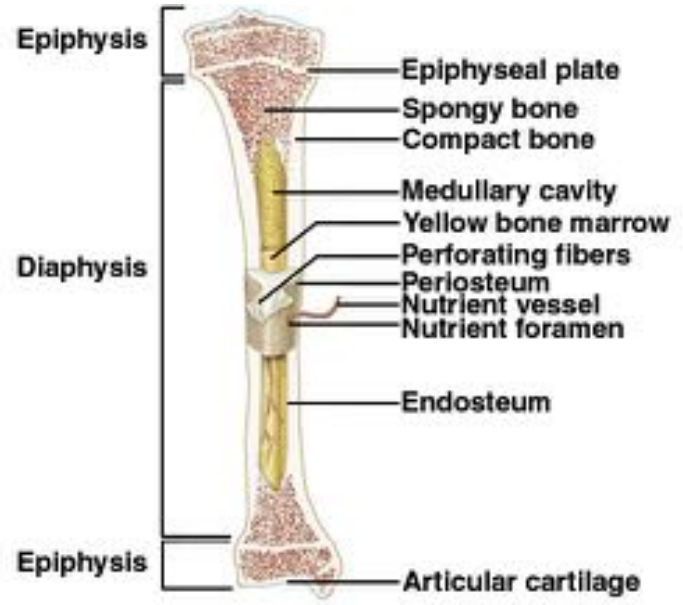
- Supports the body and muscles
- Protects and encloses visceral organs
- Helps in movement
- Blood formation in bone marrow
- Stores minerals and salts like calcium, phosphorus
- Removes foreign and toxic heavy metals

Types of Bones

- **Long:** tubular and hollow on the inside designed for more movement (found in arm and leg bones)
- **Short:** cuboidal in shape (wrist and ankle bones) include carpal and tarsal bones
- **Flat:** cranial bones, sternum
- **Irregular:** Vertebrae, bones of the face
- **Other:** Pneumatic (air-filled bones e.g. nose bones), sesamoid (bones in tendons) and accessory (sometimes present)
- There are 206 bones in the human body (children have more which can fuse upon adulthood)

Bone composition

- Bones are composed of two cell types:
    - ❖ Osteoblasts: bone producing cells
    - ❖ Osteoclasts: bone dissolving cells
- Apart from the cells, bones contain extracellular matrix which is:
    - ❖ 2/3rd inorganic: composed of mineralised ground substances (85% hydroxyapatite (crystallised calcium phosphate); 10% calcium carbonate and other minerals)
    - ❖ 1/3rd organic: collagen fibres, protein, carbohydrate molecules
- Minerals resists compression while collagen resists tension



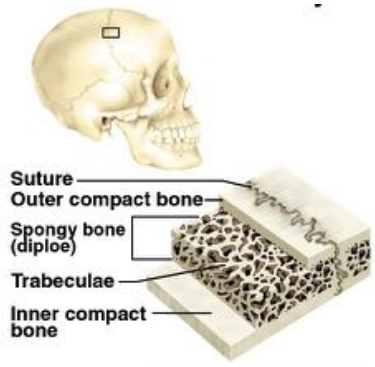
Structure of Long Bone

- **Periosteum:** membrane that covers the outer surface of all bones, except at joints (articular cartilage instead)
- **Compact bone:** dense bone with solidly filled matrix filled with organic ground substance and inorganic salts (3/4 of weight)
- **Spongy bone:** many open spaces connected by flat planes of bone known as **trabeculae** (this contains osteoblasts & osteoclasts)

- **Diaphysis:** the shaft or central part of the bone
- **Epiphysis:** the end part of the long bone, which initially grows separately from diaphysis
- **Epiphyseal plate:** a hyaline cartilage plate (high amounts of collagen) located at end of long bone where new bone growth takes place
- **Nutrient foramen:** an external opening for entrance of blood vessels into the bone; leads into a nutrient canal
- **Endosteum:** a thin vascular membrane of connective tissue lining the inner surface of bony tissue which forms medullar cavity of long bones
- **Medullary cavity:** central cavity of bone shafts where red bone marrow and/or yellow bone marrow is stored:
    - ❖ RBM is important for the growth of new bone (produces new RBCs, WBCs and platelets)
    - ❖ YBM produces fats, cartilage and bone

Structure of Flat bone

- External and internal layer of compact bone with a middle layer of spongy bone (called the diploe); there is no marrow cavity
- Contains air-filled bubbles known as **trabeculae**
- Flat bones are a life-long repository of RBM



Properties of Bone

- Trabecular bone (air-filled) is good at resisting static forces (involving weight)
- Cortical bone is denser bone and good at resisting dynamic forces (e.g. bending)

Types of Cartilage

- Cartilage is the precursor for most bones
- There are 3 types of cartilage: **hyaline, fibro & elastic**

Hyaline	**Fibro**	**Elastic**
- Located on articular surfaces (ends of bone) - Composed of parallel collagen fibres - Has a glossy appearance - Is the model for foetal skeleton	- Designed to withstand high pressure - Forms discs, meniscus, labrum - Composed of dense, irregular collagen fibres	- Contain elastic collagen fibres - Need to be able to expand - Have a small supply of nerves - Located in external ear, auditory tube, parts of larynx

Bone formation (Ossification)

- Intramembranous ossification: forms flat bones of skull, clavicle, mandible; uses a **fibrous cartilage precursor**
- Endochondral ossification: forms long bones and most other bones; uses a **hyaline cartilage precursor**
- Bone first appears between weeks 6-8 of intrauterine life

Intramembranous	**Endochondral**
- Produces flat bones of skull and clavicle - Mesenchymal Stem Cells (MSCs) initiate the process (they are in mesenchyme) - The mesenchyme transforms into a network or soft trabeculae	- Produces long bone - Starts from a hyaline cartilage model - Bone begins to appear in the middle of the shaft (primary centre of ossification) - Cartilage is progressively replaced by bone, which extends towards the ends (epiphyses)

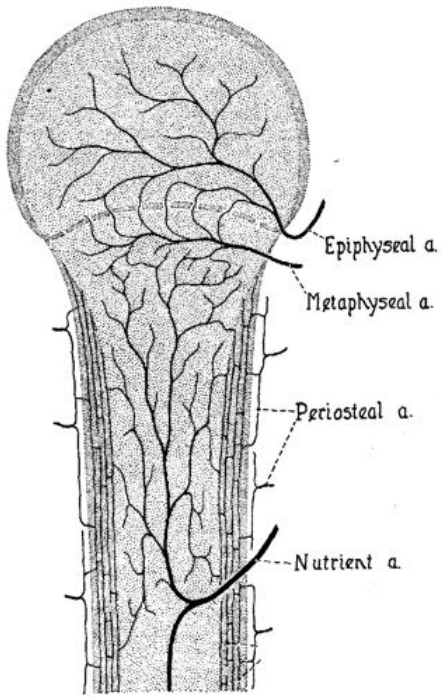
- Trabeculae contain osteoblasts, which gather to form osteoid tissue (uncalcified bone) - Osteoclasts remodel the centre to contain marrow spaces while osteoblasts remodel the surface to form compact bone - Mesenchyme at surface gives rise to periosteum	- Bone is simultaneously formed in periosteal and endosteal layers to remodel medullary cavity - The primary centre is invaded by the **nutrient artery** which enters via the nutrient foramen into the **nutrient canal** directed away from growing end - It brings osteogenic cells such as osteoblasts & osteoclasts

Endochondral cont.

- The developing bone can be categorised into **diaphysis, epiphysis & metaphysis**
- The epiphysis is the site of most metabolic activity due to growth occurring here
- The epiphyseal growth plate is located between meta and epiphysis and is only found in growing bone
- Secondary centres of ossification appear at epiphyses whereby epiphyseal arteries invade to deposit osteoblasts and erode cartilage
- Generally, two different types of epiphyses are possible: 'pressure' associated with joints and 'traction' associated with attachments of tendons to ligaments

Epiphyseal Growth Plate

- The epiphyseal growth plate mediates continued longitudinal growth (longer); cartilage cells on the epiphyseal surface progressively mature and die to be replaced by bone at metaphyseal surface; after full development the only remaining cartilage is *articular cartilage* at the ends of bone (this is required to mediate bone-on-bone movements)
- Epiphyses have great significance as they can indicate whether a bone is still growing and provide good indication of skeletal age in a forensic situation; damaged epiphyses can interrupt growth at site
- **Achondroplasia** is a genetic disease whereby long bones stop growing prematurely as chondrocytes in metaphysis fail to multiply and enlarge



Neurovascular supply of Bone

There are 4 types of arteries that supply a long bone:

- **Nutrient** provide osteoblasts to initiate ossification at the primary centre
- **Periosteal** supply the periosteum
- **Metaphyseal** supply the metaphysis
- **Epiphyseal** supply the epiphyses
- Supplied by 'end arteries' which are terminal arteries supplying oxygenated blood to tissues; and 'anastomoses' which are connections between blood vessels allowing for formation of vascular networks
- Bone also receives abundance of sensory and pain nerve fibres
- Lymph vessels accompany blood vessels

Fractures

- **Simple fracture:** fracture doesn't penetrate skin
- **Compound fracture:** penetrates skin
- Fractures can be associated with tearing & stripping of periosteum, especially with displacement of broken ends
- Displacement of periosteum can lead to bone fusion
- Other defects include **osteophytes (bone outgrowths)** and **compression fractures** which can impinge on spinal nerves causing considerable pain
- **Ectopic bones** are another defect whereby there is an abnormal formation of bone is other tissues

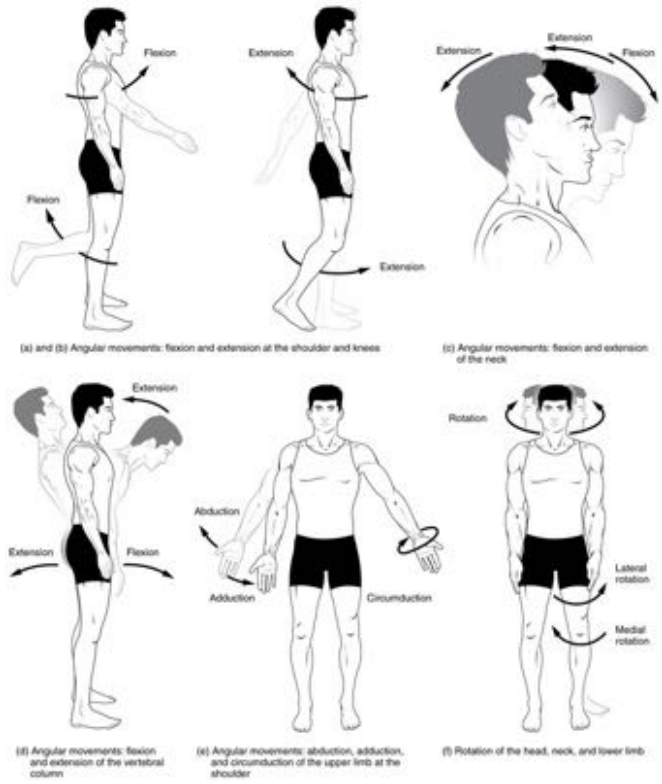
Lecture 20 – Articular System and Joints

- Articular System: joints of the body and associated ligaments
- Types of joints include **fibrous, cartilaginous, synovial**

Type	Features
Fibrous	- Held together by fibrous tissues - Examples include **suture** (between skull bones), **syndesmosis** (fibrous tissue linking long bones e.g. distal tibia & fibula) and **gomphosis** (tooth held in socket by periodontal ligament)
Cartilaginous	- Held together by cartilage - Can be separated in **primary** and **secondary** - Primary cartilaginous joints include hyaline cartilage b/w bones which disappear during development (e.g. epiphyseal plate) - Secondary cartilaginous joints are wedge of fibro cartilage b/w layers of hyaline cartilage (e.g. intervertebral disc); located in the midline
Synovial	- Bones separated by joint cavity - Enclosed in fibrous joint capsule - Lubricated by synovial fluid - Allow extensive movement - Tend to be associated with limb and limb girdles

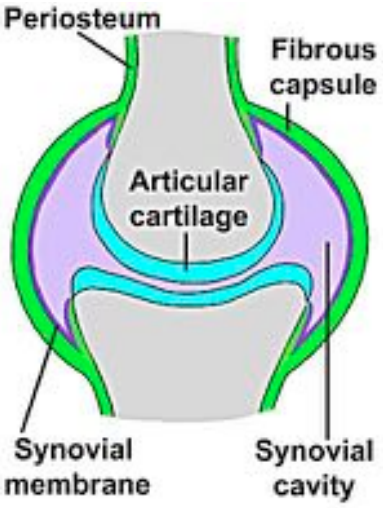
Synovial Joints cont.

- Can be uniaxial (one plane of rotation), bi-axial (two planes of rotation) or multi-axial
- Can also be distinguished based on number of articular surfaces:
    - ❖ Simple SJs: have one pair of articular surfaces
    - ❖ Compound: have more than one pair (e.g. elbow and knee joints)
    - ❖ Complex: joint cavity subdivided into more than one joint compartment (fibrocartilaginous disc: TMJ, Sternoclavicular; incomplete menisci: Knee joint) allow separate movements to occur but maintain stability



Movement of Bones at Synovial Joints

- Flexion/extension along the sagittal plane
- Abduction/adduction along the coronal plane
- Rotation (medial & lateral) along the transverse plane



Features of Synovial Joint

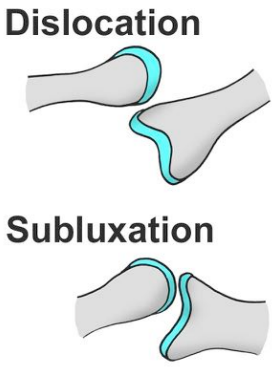
- **Articular cartilage** is avascular and aneural
- **Fibrous capsule** which normally attaches at site of epiphyseal plate
- **Synovial cavity**
- **Synovial membrane** lines all non-articular surfaces
- **Ligaments**
- **Special structures:** labrum, disc, menisci, intracapsular tendon, bursae, fat pad

Structure	Feature
Fibrous capsule	- Encloses the joint and is reinforced by (intrinsic) ligamentous thickenings - May have muscles attached or openings to permit access of communicating structures (e.g. tendons, bursa) - Receives a rich sensory nerve supply of proprioceptive (stretch & joint position) and pain fibres - Fibrous capsule and ligaments receive poor blood supply

Synovial membrane	- Capsule lined by synovial membrane, which secretes synovial fluid into the joint space; this fluid acts a lubricant and nutrient for underlying cartilage - The synovial membrane is highly vascular - **Injuries** to the SM include effusion (excess synovial fluid in cavity through mild irritation of synovial membrane); haem arthrosis (bleeding into joint cavity through tear of synovial membrane; septic arthritis (microorganisms in joint cavity through penetrating injury; danger of permanent joint destruction)
Ligaments	- Composed of collagen fibres designed to resists tensile forces - Provide mobility and stability for the joint - Intrinsic ligaments reinforce capsule - Extrinsic ligaments separate from capsule (extracapsular/intracapsular) - Accessory ligaments are located at a distance from joint - Connect bones to other bones to form joints - **Injury:** Type I (minimal disruption to fibres); Type II (up to 50% disruption; clinic laxity (looseness); Type III (complete rupture with 10%-20% strain); can lead to avulsion injury (a portion of cortical bone is ripped from the rest of the bone by the attached tendon - Ligaments with multiple bands attached to multiple bones are the most susceptible to injury
Labrum	- Fibrocartilaginous rim allows for deepened socket for 'ball and socket' joints allowing for multiaxial rotation - Rotation in the rim is not painful as it composed of fibrocartilage - Is avascular and receives nutrition from synovial fluid
Discs & Menisci	- Provide separation between the bones - Meniscus is made of fibrocartilage allowing joints to withstand compressive forces - Receives a bit of blood supply at the periphery (outer third)
Intracapsular tendon	- Helps stabilise the joint and facilitates rotation - Covered by synovial membrane for lubrication

Bursae	- Fluid filled pockets of synovium (double layer of synovial membrane) - Provide lubrication and reduce friction - Bursae that lie close to the joint and make contact are 'communicating bursae' and can spread infection to the joint cavity; 'non-communicating bursae' contain the infection
Fat pads	- Found in joints that are mobile; help spread synovial fluid through the joint (are extra-synovial) - Act as shock absorbers - Possess nerve and blood supply

Joint Injury



- Some joints are prone to subluxation or dislocation
- Bones with maximum stability have tight capsule
- Bones with loose capsule are less stable and thus prone to injury

Neurovascular Supply of Joints

- Joint capsule and ligaments have rich proprioception and pain fibres
- The articular surface is covered by hyaline cartilage and is aneural and avascular
- **Hilton's law**: nerves supplying muscles that move joints also supply the joints
- Rich blood supply to synovial membrane to the bone and joint from surrounding muscles; poor blood supply to fibrous capsule and ligaments
- Fibrocartilage is aneural and avascular except at the periphery

Arthritis & Artificial joints

- **Arthritis** is broad term for pain & inflammation
- **Osteoarthritis** is a result of years of joint wear (articular cartilage softens and degenerates; bone spurs develop on exposed bone tissue causing pain)
- **Rheumatoid arthritis** is an autoimmune attack on joint (antibodies attack synovial membrane; enzymes in synovial fluid degrade cartilage; bones ossify)
- **Arthroplasty** is the replacement of diseased joint with artificial device (**prosthesis**)